Breakage Tester Predicts Handling Damage in Corn

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Lyle E. Stephens and George H. Foster[1]

Corn harvested mechanically and dried artificially often breaks when handled. Repeated handling may increase the broken corn content of grade No. 1 or 2 corn sufficiently to lower it to sample grade. Corn is sample grade when broken corn plus foreign material exceeds 7 percent.[2] Breakage in export corn that is handled many times frequently exceeds 7 percent, according to the U.S. General Accounting Office.[3] Breakage is defined as broken kernels and fine material that will pass through a 12/64-inch diameter (4.8 mm) round-hole sieve. When a storage bin is filled, broken corn and foreign material often concentrates in a small area under the filling spout and increase the hazard of mold or insect activity in that area. This creates problems in maintaining grain quality in storage.

Foster and Holman[4] reported a study of grain breakage caused by commercial handling methods. They found that dropping corn 70 feet onto a pile of corn produced 4 to 7.7 percent breakage, that one pass through the boot of a bucket elevator produced 0.2 to 3.2 percent breakage, and that a 100-foot fall through a flexible spout impacting a steel surface (simulating filling a boxcar) could produce 1.5 to 7 percent breakage. The exact breakage percentage was dependent on the moisture content and temperature of the corn, but these variables were at levels typical of corn in commercial trade. Apparently grain that is highly susceptible to breakage creates a problem for all who handle it.

Current harvesting and drying methods contribute greatly to breakage in shelled corn. Thompson and Foster[5] investigated the effects of harvesting and drying methods on the formation of stress-cracks and breakage in corn. They found that kernels with stress-cracks, which contribute to breakage susceptibility, were prevalent in heat-dried corn although practically nonexistent in crib-dried ear corn. Corn that was field-shelled at 30 percent moisture content was damaged by the sheller and produced about twice as much breakage after drying as did hand-shelled corn. The amount of breakage after drying was reduced when the corn was harvested at low moisture contents and dried at low temperatures and at low drying airflow rates.

Three breakage testers or testing methods were evaluated by Thompson and Foster. Of the three, the Stein breakage tester gave the most consistent measure of breakage susceptibility. They found both the sample moisture content and the temperature had a major effect on sample breakage. However, no attempt was made to relate the breakage reported to that occurring in normal handling operations in the grain trade.

McGinty[6] reported that of the two mechanical breakage devices he tested, the Stein breakage tester was superior and could be used to predict the "breakage tendency" of the grain. He investigated the effects sample moisture content and tester running time had on breakage level in corn, wheat, and soybeans and suggested a 2-minute test with the Stein unit. He also found much higher breakage in heat-dried corn than in corn dried naturally. McGinty was concerned with test standardization and the repeatability of results obtained with a given breakage tester and between different testers of the same design but he did not relate the breakage tester results to breakage in normal handling.

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[1]Agricultural engineers, U.S. Grain Marketing Research Center, Agricultural Research Service, U.S. Department of Agriculture, 1515 College Ave., Manhattan, Kans. 66502

[2]U.S. Dept. Agr., Official grade standards of the United States. Agricultural Marketing Service. 1970.

[3]U.S. General Accounting Office. Assessment of the national grain inspection system. RED-76-71, 119 pp. 1976.

[4]Foster, G. H., and Holman, L. E. Grain breakage caused by commercial handling methods. U.S. Agr. Res. Serv. Mktg. Res. Rpt. 968, 13 pp. 1973.

[5]Thompson, R A., and Foster, G. H. Stress cracks and breakage in artificially dried corn. U.S. Agr. Res. Serv. Mktg. Res. Rpt. 631, 24 pp. 1963.

[6]McGinty, R. J. Development of a standard grain breakage test. U.S. Agr. Res. Serv., ARS 51-34, 13 pp. 1970.

The Stein breakage tester was evaluated as a part of a study conducted to determine the extent of breakage and to evaluate methods to reduce the breakage of shelled corn in elevator handling systems. The breakage occurring in actual handling of shelled corn was compared to that predicted by the Stein tester.

Equipment and Procedure

The Stein breakage tester is an adaptation of a mill for grinding grain and other materials for laboratory analyses (fig. 1). The cutter blade is replaced by an impeller, which rotates at high speed in the bottom of a sample cup. The grain sample is placed in the cup and repeatedly impacted against the top of the cup by action of the impeller which is run for a predetermined time. The grain sample is then screened to measure the percentage of broken kernels.

The study on grain handling was limited to the problem of reducing damage to corn moving through gravity spouts. In one test series, two flow retarders were used singly and in combination in a grain spout. The spout system and the various flow retarder combinations, 1 through 4, are shown in figure 2. This system was operated at a grain flow rate of 2,000 bushels per hour.

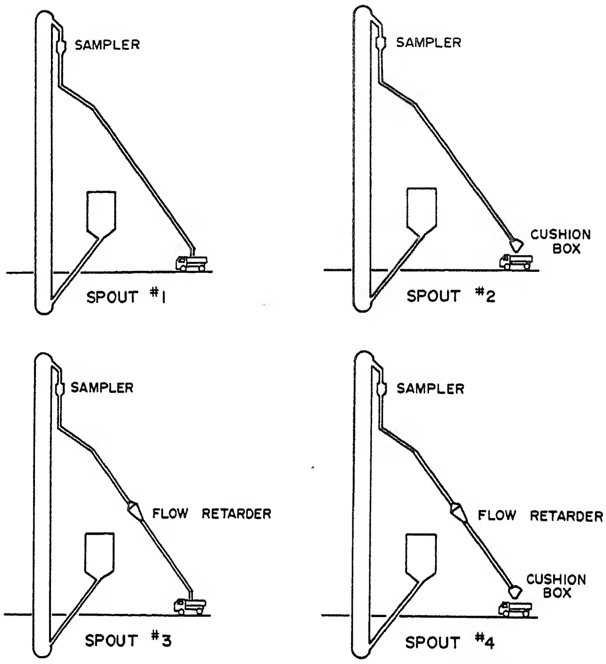


Figure 2.—Grain spouts used in first test series.

In a second test series, an experimental flow retarder using a fan powered by an electric motor was installed at the end of the grain spout and replaced the flow control devices shown in figure 2. This retarder was operated with grain flow rates of 800 and 1,400 bu/hr. Similar tests were conducted without the retarder fan in operation, giving four test combinations: 800 bu/hr—fan off; 800 bu/hr—fan on; 1,400 bu/hr—fan off; and 1,400 bu/hr—fan on.

The corn used in the first test series was from a single field of one variety and was divided into three sublots. Each sublot was dried by a different method: field drying to 15 percent moisture before harvest, low temperature (100° to 130° F) bin drying, and high temperature (200° to 220° F) batch drying. A sublot conditioned by each drying procedure was tested three times through each of the four different spout arrangements.

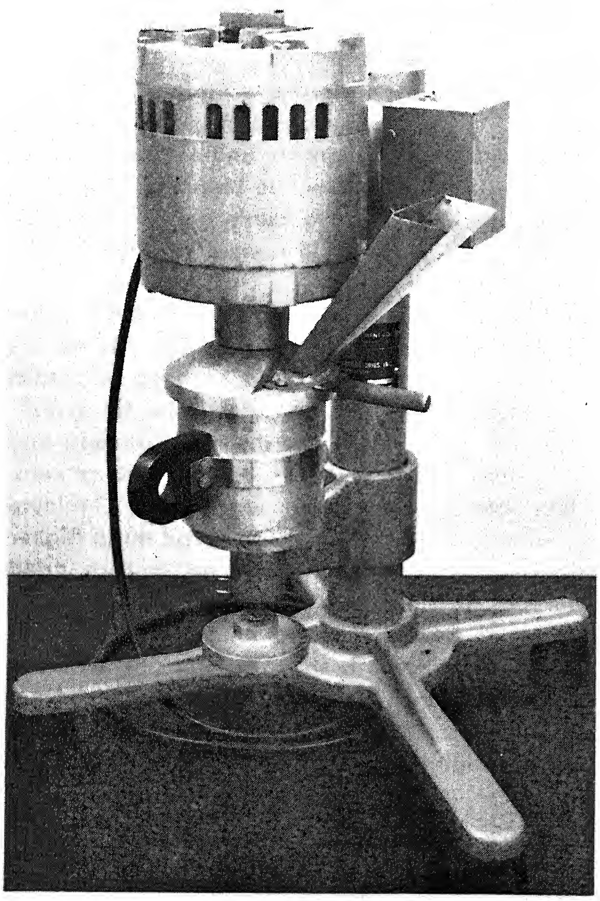


Figure 1.—Stein breakage tester.

Three different batches of corn were used in the second series of tests. Two batches labeled A and B had been dried in bins with unheated air. The third batch labeled C was obtained from Commodity Credit Corporation stocks. Its history was unknown. Because the supplies of corn were limited in size, the same corn was not used for all test conditions. As in the first test series, each test lot was used three times before being discarded.

For a test run the corn was removed from a storage bin, elevated, and dropped through a spout into a truck. Samples were taken from the grain stream by a mechanical spout sampler located near the top of the spout run. The entire lot was screened with a rotary cleaner equipped with a 12/64-inch round hole screen as the truck was unloaded. The initial spout sample was screened on a hand sieve. The initial breakage level was subtracted from the final breakage level to determine the breakage increase for the test.

The initial sample from each handling test was used for the breakage test to predict the breakage susceptibility of each test lot. Before running the breakage test, the sample corn was screened on the 12/64-inch round hole sieve to remove any breakage initially present. The moisture content of the material remaining on the sieve was measured on an electronic moisture meter. The samples had been held in polyethylene bags to reduce changes in moisture content between collection and testing, but the samples had warmed to room temperature before testing. Breakage tests were conducted on three 100-gram subsamples taken from the screened sample. For each test the breakage tester was operated 4 minutes. The corn was then removed from the tester and again screened on the 12/64-inch round hole sieve. The material remaining on the sieve was weighed and the weight loss calculated and recorded as the tester breakage in percent.

Results and Discussion

The comparisons between breakage indicated by the Stein breakage tester and the actual handling breakage are illustrated in figures 3 and 4. Because each spout combination or flow condition may produce a different amount of handling breakage, each is plotted separately. The high correlation coefficients noted on the figures indicate that differences in the tester breakage successfully predict differences in actual handling breakage. Each datum point in figures 3 and 4 is an individual breakage tester measurement as given in tables 3 and 4. In the tables note the small spread in tester breakage among the three replicated measurements.

The 4-minute running time of the tester used in this work produced a wide spread in breakage between corn lots. In none of the 11 or 12 tests made with each lot of corn did either the tester breakage or the handling breakage of any lot overlap that from any test of the other 2 lots shown in figure 3. In other words, the lots were separated according to brittleness with 100 percent reliability under the conditions of these tests. The results in figure 4 are quite similar.

The data in table 1 are the same test data shown in figure 3 but summarized according to the drying treatment of each corn lot. As drying stress was increased, both the handling breakage and the tester breakage increased. The tester breakage increased from 3 percent for the lot dried in the field to 36.6 percent for the corn dried artificially at high temperatures. This is a twelvefold increase. The actual handling breakage for the same two lots increased from 0.9 percent to 5.8 percent, a six- to sevenfold increase. The range of breakage for the 11 or 12 individual tests conducted with each of the 3 corn lots did not overlap and shows the same clear separation of the 3 corn lots that can be seen in figure 3.

The data in table 2, also grouped by corn lots, are the same data illustrated in figure 4. Although the history and treatment of these lots were not known completely, evidently lot A was less brittle than lots B and C. The tester breakage and the actual breakage in lot A are approximately half that of lots B and C.

Table 1.—*Breakage tester indicates percentage differences in handling damage in corn related to drying treatment*

Drying treatment[1]	Number of tests	Moisture content average	Tester breakage		Handling breakage	
			Average	Range	Average	Range
Dried in field	11	13.3	3.0	2.1- 4.6	0.9	0.6-1.2
Dried at low temperature	12	12.5	11.6	7.9-16.2	2.5	1.8-3.4
Dried at high temperature	12	11.4	36.6	28.8-43.7	5.8	4.2-7.5

[1]See page 2 for details of drying treatment.

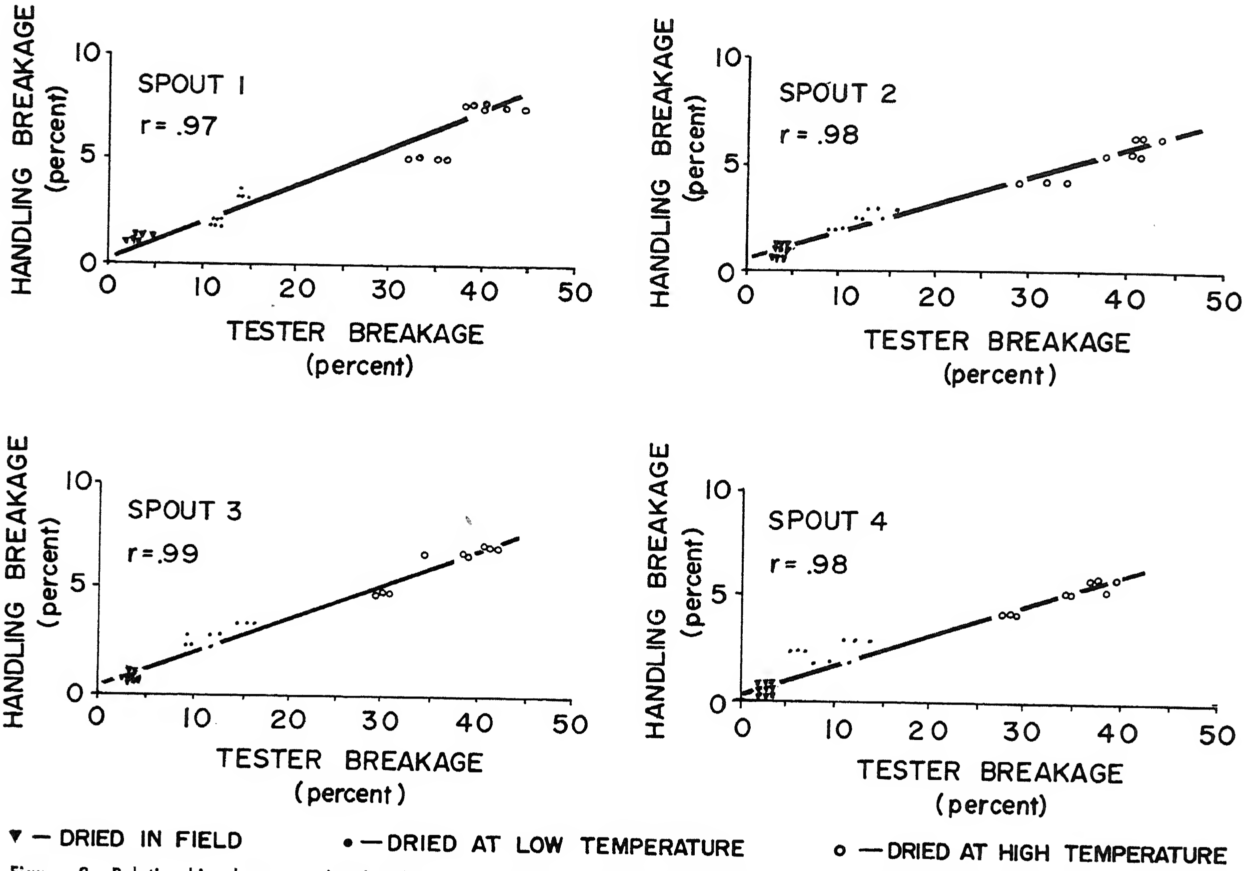


Figure 3.—Relationship between the breakage determined by the Stein tester and the actual breakage from handling in the four spout systems.

All of the differences in breakage shown in table 1 are not likely attributable to differences in drying treatment. The lot of high-temperature dried corn was at a moisture content nearly 2 percentage points lower than the field dried corn. The lot dried at moderate drying temperatures was at a moisture content between that of the other two lots. Thus, part of the difference in the tester breakage and handling breakage was due to these differences in moisture content. However, in breakage tests, we are interested in predicting breakage of the lot of grain in the condition it will be handled, regardless of the cause of the brittleness. The important consideration is to be sure that the sample being tested to determine breakage susceptibility is at the same moisture content, and preferably at the same temperature, as the corn making up the lot sampled. Maintaining moisture content of the sample is not likely to be as big a problem in practice as maintaining the temperature of the sample. However, if the corn is cold when the sample is drawn, water may condense on the sample if it is brought into a warm room and put into a warm tester. Condensation on the sample will affect breakage. McGinty[7] showed that tempering (adding moisture to the sample) reduced the brittleness indicated by the breakage tester.

The breakage tester was operated 4 minutes in these tests. With the corn we were using, this gave excellent separation of the lots according to brittle-

Table 2.—*Breakage tester indicates percentage differences in handling damage in miscellaneous corn lots*

Corn lot	Flow rate Bu/hr	Number of tests	Moisture content average	Tester[1] breakage	Handling[1] breakage
A	800	6	13.1	9.5	1.2
A	1,400	6	13.2	8.5	1.8
B	800	6	11.0	17.9	3.2
C	1,400	6	12.2	20.9	3.3

[1]Data are averages of tests with experimental flow retarder both on and off at the flow rate shown.

[7]See footnote 6, p. 1.

Table 3.—*Test conditions and breakage measurements from three drying treatments*

Drying treatment	Flow retarder combination[1]	Handling number	Moisture content	Tester breakage Rep 1	Tester breakage Rep 2	Tester breakage Rep 3	Handling breakage
			Percent	*Percent*	*Percent*	*Percent*	*Percent*
Dried in field	1	2	13.0	2.52	2.85	2.79	1.10
do	do	3	13.0	3.25	4.56	2.95	1.22
do	2	1	13.3	3.00	2.85	3.31	.57
do	do	2	13.7	3.12	2.95	3.22	.99
do	do	3	13.5	3.60	3.92	3.20	1.03
do	3	1	13.1	3.28	2.82	2.89	.76
do	do	2	13.2	3.95	3.05	3.04	.73
do	do	3	13.2	3.22	3.10	3.10	.79
do	4	1	13.4	2.49	2.08	2.90	.81
do	do	2	13.5	2.63	2.76	3.73	.55
do	do	3	13.7	2.30	2.32	2.71	.63
Dried at low temperature	1	1	12.5	11.50	9.43	9.82	1.79
	do	2	12.5	11.02	11.20	10.30	2.02
do	do	3	12.5	14.47	13.93	13.57	3.44
do	2	1	12.7	10.97	8.24	9.55	1.97
do	do	2	12.5	14.24	11.59	11.21	2.32
do	do	3	12.2	12.48	15.24	13.67	2.88
do	3	1	12.4	9.09	11.67	9.21	2.25
do	do	2	12.4	9.10	12.78	11.83	2.88
do	do	3	12.2	16.24	15.53	14.10	3.15
do	4	1	12.8	11.16	7.85	9.39	1.92
do	do	2	12.9	11.55	10.15	10.62	2.07
do	do	3	12.9	13.55	10.52	11.71	2.76
Dried at high temperature	1	1	11.4	35.52	34.61	31.08	5.00
	do	2	11.4	37.58	39.93	37.72	7.52
do	do	3	11.1	41.75	43.73	39.31	7.32
do	2	1	11.4	31.50	33.55	28.75	4.22
do	do	2	11.3	40.82	37.49	40.22	5.24
do	do	3	11.4	40.79	40.71	43.20	6.21
do	3	1	11.4	29.62	31.32	35.10	4.97
do	do	2	11.4	38.15	38.30	34.30	6.56
do	do	3	11.3	42.00	41.64	41.68	6.93
do	4	1	11.8	28.80	27.82	29.35	4.16
do	do	2	11.6	38.28	34.30	34.22	5.10
do	do	3	11.6	39.18	36.70	37.08	5.86

[1]See figure 2 for flow retarder combinations.

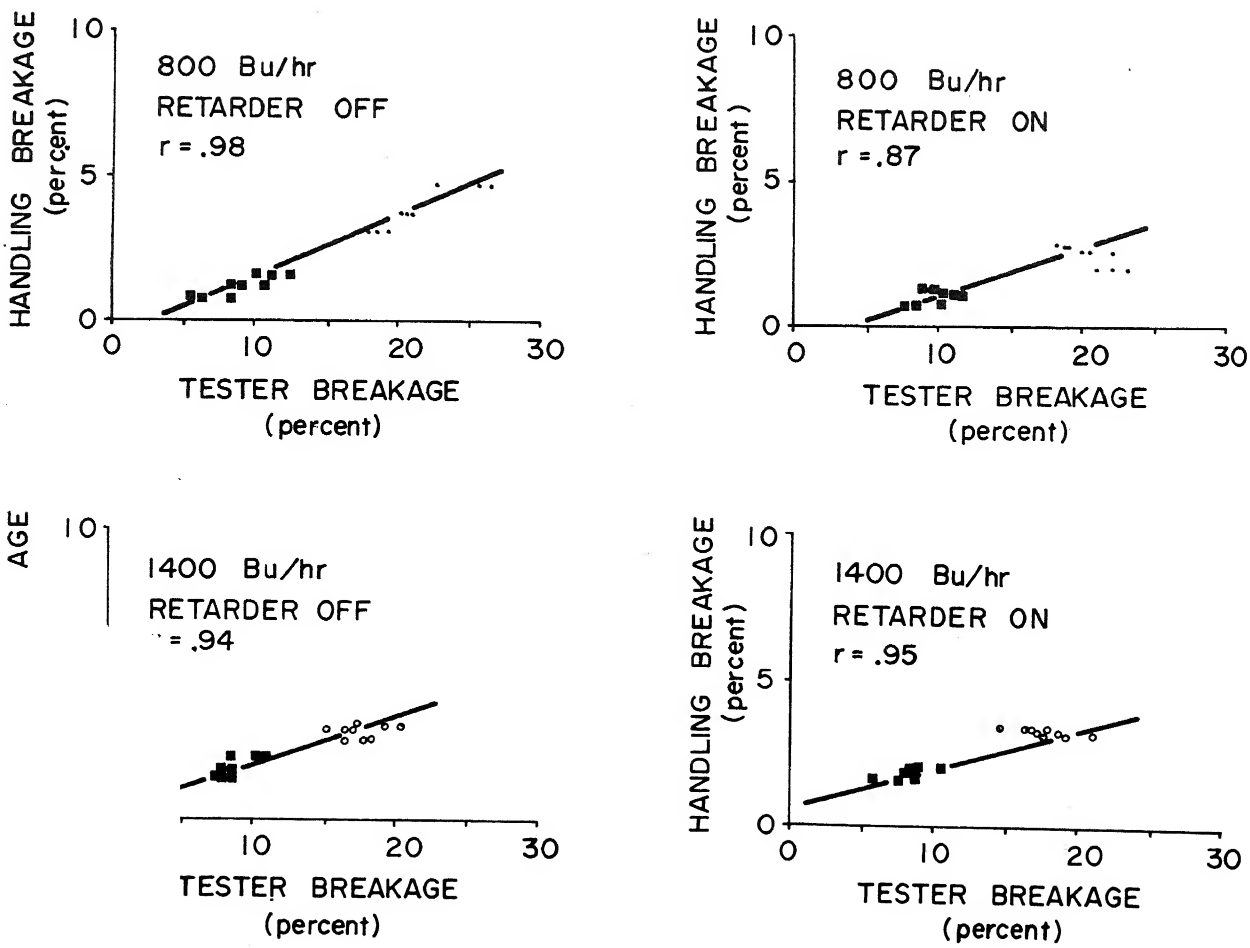
ness. For more brittle corn, 4 minutes may be too long. Separation of lots cannot be made if there is nearly 100 percent breakage in all tests. The length of the test may need to be adjusted so there will be some breakage in all samples.

The breakage tester indicates only breakage susceptibility; the actual breakage will depend on the number and severity of the handling operations to which the grain is subjected. However, for any given set of handling operations, the breakage test will show the relative breakage susceptibility of different lots of corn. Grain found to be breakage prone can be directed to local uses involving minimum handling or be held for sale to users for whom a high breakage level is no problem. Conversely, grain with low breakage susceptibility can be directed to users who need whole kernel corn or to other destinations, including export, that involve repeated handling.

Standardization of the testing procedure and the equipment will be required if the breakage tester is used in official grading procedures. However, elevator operators and others using the tester to indicate relative breakage susceptibility of lots of grain they handle need only to operate a given tester in a consistent manner and to make sure that the sample tested is at the same conditions as the lot from which it was drawn.

Table 4.—*Test conditions and breakage measurements from three corn lots in experimental flow retarder*

Corn lot	Flow rate	Flow retarder fan	Handling number	Moisture content	Tester breakage Rep 1	Tester breakage Rep 2	Tester breakage Rep 3	Handling breakage
	Bu/hr			*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
A	800	Off	1	13.0	8.19	6.25	5.60	0.86
do	do	do	2	13.2	8.25	10.50	8.65	1.33
do	do	do	3	13.2	10.15	11.15	12.87	1.66
do	do	On	1	13.2	7.80	8.47	10.02	.80
do	do	do	2	13.2	11.40	10.32	11.45	1.29
do	do	do	3	13.0	9.71	9.73	9.70	1.32
do	1,400	Off	1	13.5	7.75	7.92	8.95	1.51
do	do	do	2	13.2	8.36	8.96	8.84	1.74
do	do	do	3	13.0	10.69	10.52	8.59	2.14
do	do	On	1	13.4	5.87	7.67	7.98	1.62
do	do	do	2	13.2	7.79	8.10	8.06	1.69
do	do	do	3	13.2	8.76	10.06	8.51	1.83
B	800	Off	1	11.4	19.25	18.32	17.72	3.09
do	do	do	2	10.9	20.32	20.45	20.55	3.85
do	do	do	3	11.1	25.40	26.13	22.18	4.70
do	do	On	1	10.8	18.72	18.80	19.10	2.95
do	do	do	2	10.9	22.12	23.07	21.02	2.13
do	do	do	3	10.9	20.20	20.52	22.10	2.84
C	1,400	Off	1	12.2	18.10	16.81	18.40	2.79
do	do	do	2	12.3	19.73	20.95	17.40	3.35
do	do	do	3	12.1	17.19	15.88	16.75	3.28
do	do	On	1	12.2	17.80	18.97	17.77	3.35
do	do	do	2	12.3	21.00	19.06	17.62	3.25
do	do	do	3	12.2	16.42	14.82	16.90	3.46



ORN LOT A • — CORN LOT B o — CORN LOT C

hip between the breakage determined by Stein breakage tester and the actual breakage from handling in an experimental flow retarder.

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